Climate change effect on the South Iraq stormwater network

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Abstract: The important issue that municipalities face is the process of urban flood control and monitoring due to the damage these floods cause to infrastructure . To reduce potential climate change risks, the aim of this study was to develop a decision to determine the efficiency of stormwater networks in Basra, Iraq. Based on the data obtained from 1979 to 2018, the Storm Water Management Model (SWMM) program was used to simulate the stormwater network in Basra, as well as use this data to predict the annual precipitation in the future until 2099 using the Statistical downscaling Model (SDSM). The results indicate a future rise of (0.14 to 1.07)°C as a maximum temperature. As a result of climate change, the intensity of rain is expected to increase beyond the network capacity to reach 21.5 mm/hr, given that the design capacity of the network is 11.5 mm/hr, this lead to overflow 34% of manholes**.**

Keywords: SWMM, SDSM, Climate change, Storm water network.

1 Introduction

The change in climate parameters, such as rainfall, temperature, wind speed, humidity,..etc.,is climate change. And so, the parameters of precipitation and temperature have a major effect on flooding. Flooding can be described as a stormwater system's failure to accommodate water entry. There are many reasons for floods, such as climate change, changes in land use, urbanization, and population accumulation. There are several studies that have used the SWMM program for the purpose of determining to flood in rainwater networks.

The Intergovernmental Panel on Climate Change (IPCC) state that an increase in temperature of between 1˚C and 3.5˚C due to rising in greenhouse gases by the end of this century [1-4] and[5]state that is rising in sea level between 13 and 94 cm.

In Mission / Wagg Creek watersheds in British Columbia, Canada, the increase in the intensity of rain and the potential drainage capacity of the network was analyzed using the SWMM program, and the result was that increased short-lived rain intensity could increase in the future, however this phenomenon does not occur sharply in the framework of Mission / Wagg [6].

SWMM was used to disclose the percentage of overflow discharge decreasing due to the presence of a 70 m^3/s storage tank for a 5-year continuous rainfall event. Compared to the case of tank absence, the simulation results showed that the overflow discharge decreased from 14 percent to 20 percent[7].

A study conducted by [8] , which examined the effect on the level of surface runoff and emissions in SWMM of the division level and spatial resolution of the sub-catchment. The results showed that the surface runoff did not have that much effect on the sub-catchment division level, where the complete, cumulative, and peak impact of the runoff was marginally affected, but the pollution loads were affected same results concluded by [9–11]

In China, the proposed solutions were evaluated on the effectiveness of the rain network drainage system using SWMM, where they found that flooding decreased by 81,62% in the event that the pipe diameter increased and the flood decreased by 44.78% when the manhole sites were modified, [12 -13].

In the United States of America, metropolitan Baltimore, using the SWMM program, simulated the hydrological response affected by the increase in the rate of growth, urbanization and the age of the drainage network structure in three sub-basins, the first having a stormwater control capacity of 1%, the second 48.8% and the third 24.6%. A distinction was made between two basins, the first containing impermeable ponds and higher rainwater than the second. The efficiency of the hydrological response in both basins was similar. In the simulation, removing rainwater regulating basins leads to an increase of the peak drainage by 50%,[14].

Depending on rain data provided in Brazil improve the results of SWMM four catchments subset to simulate the drainage system to reduce the contrast between the simulation and the results observed, results showed that the value of R^2 ranged from 93% to 99% and MRE at the peak of runoff between the results observed and simulated ranged between 0.63% to 3.8%, and the average error ranged from 72.4% to 3.22%,[15].

[16] have used the SWMM model to show a single event runoff simulation impact on urban floods due to climate change in the Gunja Drainage Basin. They recommend that this has improved the SWMM peak discharge simulation at the short-term rainfall change occurred,[16], similar findings was stated by [17]

Using an SWMM model, a rainwater drainage network was simulated in Karbala, Iraq. The rain data from 2008 to 2016 were used to evaluate this network. It was assumed that the study of the impact of climate change on precipitation. The study reported that the average annual rainfall decreased in most of Iraq at the end of the 21st century,[18].

Several researchers have been used the SDSM program to downscaling climate phenomena, such as weather temperatures (to predicting the maximum and minimum temperature degrees), precipitation quantities, and air humidity percentage,[19-24] .

[25], along with SDSMs for the generation and prediction of climate data, have developed the appropriate downscaling statistical tools. Downscaling approaches seem to be adequate strategies for resolving overlapping scales by having access from global climate statistics to local climate data.

[26]. A climate change impact examination was conducted to assess the impact of temperatures and precipitation in the Western Desert of Iraq using the HadCM3 model, which predicted an increase in precipitation by

an average of 4.5% and 3.19% for the A2 and B2 scenarios respectively, and the average temperature is expected to increase between 0.51˚C to 1.01˚C in study stations.
The Middle East is mainly arid to semi-arid and often a scarce and precious resource is freshwater. The combination of a strained supply of freshwater and rapid population growth. The region's vulnerability to potential climate change is significantly growing. Simulating the region's environment is a challenge for climate models[27] .
As a case study, the effect of climate change on urban drainage systems was analyzed at the Veumdalen catchment in Fredrikstad, Norway. To test climate change through the use of expected and artificial climate scenarios. The result concludes that with a small change in precipitation, the number of flooding manholes and the number of surcharging sewers can change tremendously and irregularly, and change with events and periods. [28].
Climate change can affect groundwater supplies in many ways, where the rising of air temperatures and the different nature of precipitation water have a direct impact on groundwater drainage, storage, and levels,[29] .
Due to changing temperatures, climate change affects through precipitation, soil moisture and evaporation on the hydrological cycle, and some parts of the world can witness a major change in the time and timing of wet and dry seasons. Therefore, studying the impact of the hydrological cycle with climate changes has become very important,[30].
[31] estimate climate change in New Zealand, general circulation models (GCS) were used, in which the impact of climate change and what it causes in the occurrence of floods and droughts were assessed, and the result was an increase in the intensity of rain due to the increase in the amount of rain and its precipitation.
In order to estimate potential risks in the future, HadCM3 and CanEM2, which are models of GCMs, were dealt with using several scenarios for seven stations in southwestern Iraq. The results showed an increase in temperatures from 2020 until the end of the 21st century, which causes an increase in evaporation from surface water and thus a scarcity of water,[32].
In this research we will do the process of predicting an increase in the amounts of rain and temperatures for the southern region of Iraq, which is located near the Arabian Gulf and is characterized by high temperatures in the summer, using the SDSM program based on the data recorded by the Department of Meteorology and Seismic Monitoring in Iraq and then using the quantities of rain or Rain intensity for the purpose of analyzing it in the SWMM program for the purpose of knowing the ability of the rainwater network to drain these quantities of rain.

2 Study area

This region was chosen in this study because it is located in southern Iraq, which is characterized by high temperatures in the summer to reach more than 50 ˚C and its location overlooking the Arabian Gulf.

Al-Hussain quarter-third zone is located in the center of Basra province, Iraq between lat. (29˚ 05′ N - 31˚ 38′ N), and long. (46˚ 40′ E - 48˚ 30′ E) as shown in (Figure 1). It is approximately plane surface of low slope and mixed soil .The study area is located in a region with elevation ranges from 2.4m to 5m above the sea level. The total area are around 0.456Km^2, The permeable area in the study area is equal to 0.072Km^2, which is equivalent to 15.8% of the total area, and 0.384Km^2 are impervious about 84.2% of the total area included 0.15 km^2 of paved roads. The impenetrable area may be categorized as roofs, highways and sidewalks , the pervious are classified into gardens and dirt roads . Directly from plan maps and digital aerial picture, the impermeable percentage of the Al-Hussain quarter was calculated by computing the percentage of roofs, roads, and sidewalks at each sub catchment to the entire city. The total area is divided into (75) subcatches according to the type of land and path of the region studied. All subcapacities were directly modeled and linked to the storm drainage system. The climate in the study area is very warm, long and dry during the summers from May to October and the cold winter is brief from November to April with rain. Average winter temperatures reach 7° C and summer temperatures reach 55°C. Rainfall is few in Basra, as its annual total does not exceed 120 mm. It is seasonal starting in October with a monthly rate of less than 1 mm, reaching 29.3 mm in December and then falling to 7.8 mm in May. The average relative humidity in the city of Basra is 60%, and this percentage rises in the winter to 78% in January and decreases in the summer to 48% in August, (Agricultural Meteorology Iraqi Network (AMIN), 2018). The study area is serviced by the storm drainage network installed in 1979,it is flooding in the rainy seasons.

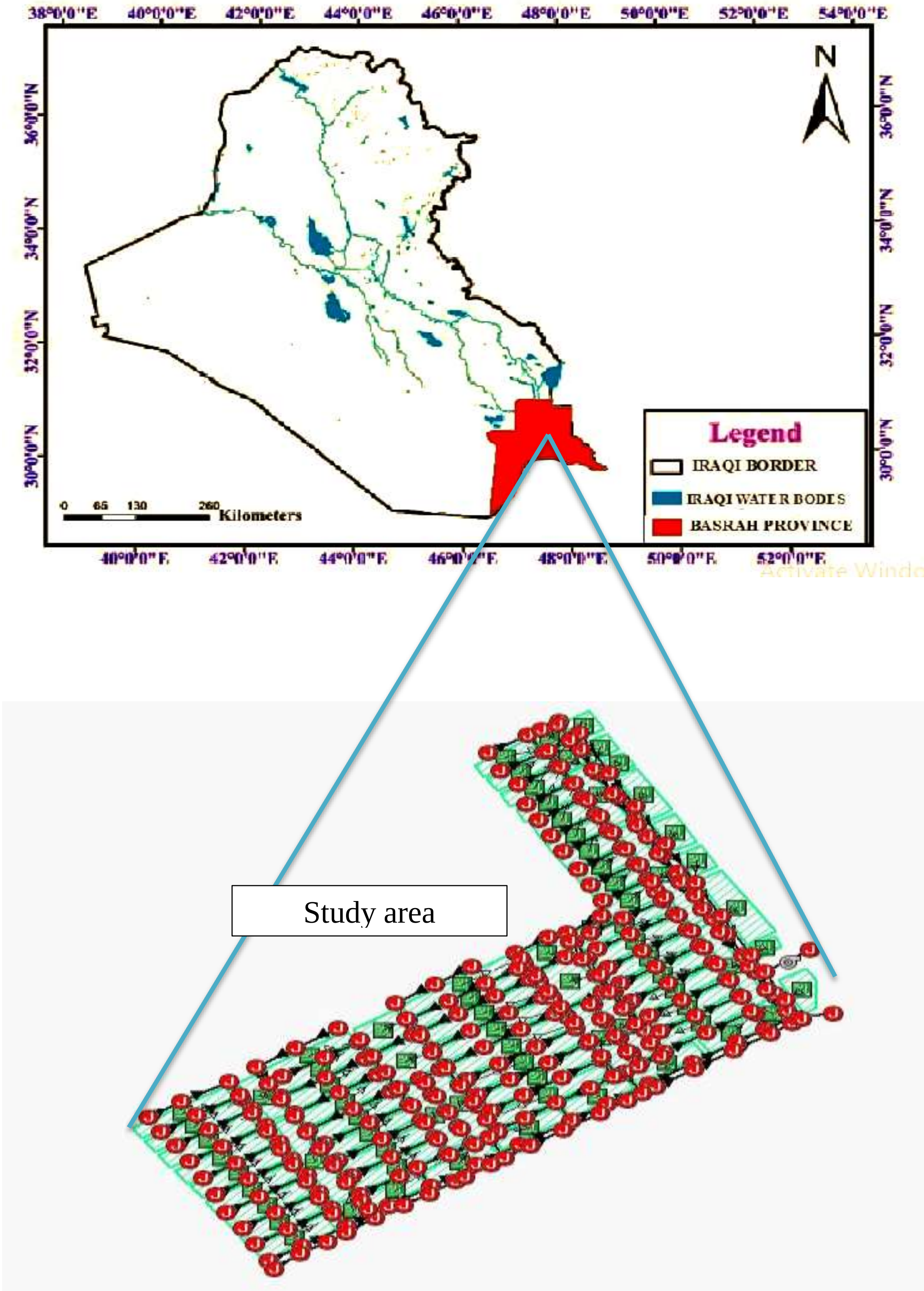

Fig. 1. Geographical location of the study area according to Iraqi map**.**

3 Materials and methods.

3.1 Analysis data.

The SDSM model was used to statistically output the production of the global circulation model(GCM) in the measurement of the temperature changes. Downscaling involves building links between global atmospheric proof as forecasters and predicted regional climate knowledge,[25]. Therefore the possibility of upgrades to the local maximum temperature ,and precipitation at a selected station is based on two data sets:-
Regular data were given on maximum temperature, and precipitation. The Meteorological and Seismological Organization in Iraq, meteorological stations in the field of research (Iraq-Basra) in its function as climate representatives during observation time (1979 to 2018).
As predictors of global climate parameters, the Canadian Climate Change Scenarios Network has taken regularly. The data included the National Center Environmental Predictions (NCEP), which has been collected for this observational period and the existing scenarios of CanESM2 production for present and future cycles (2020-2099). Downscale uses version 4.2, SDSM, two GCM data sets (currently CanESM2) [33]. Table1 shows closer mesh boxes used to gather GCM data from the weather stations analyzed from these specific grid cells. The GCM functionality for the SDSM input model is shown in table 2.

Table 1. GCM coordinate at study station scale.

GCM	Station	Basra
CanESM2	X; Y;	18 48

Table 2. GCM features used as input of SDSM model.

GCMs	SRES	Resolution	Reference
CanESM2	RCP2.6 RCP4.5 RCP8.5	2.79° × 2.81°	Canadian Centre for Climate Modeling and Analysis(CCCma).

3.2 Statistical downscaling model (SDSM).

Applied to the low GCM performance was the SDSM[34],and multiple linear regression produces climatic data(MLR). The versions of the SDSM are shown in Fig.2. The multivariable linear regression model is developed in the following steps to produce climate variables over every period (annual, monthly, or seasonal) between independent variables (global predecessors) and dependent local expected weather parameters.

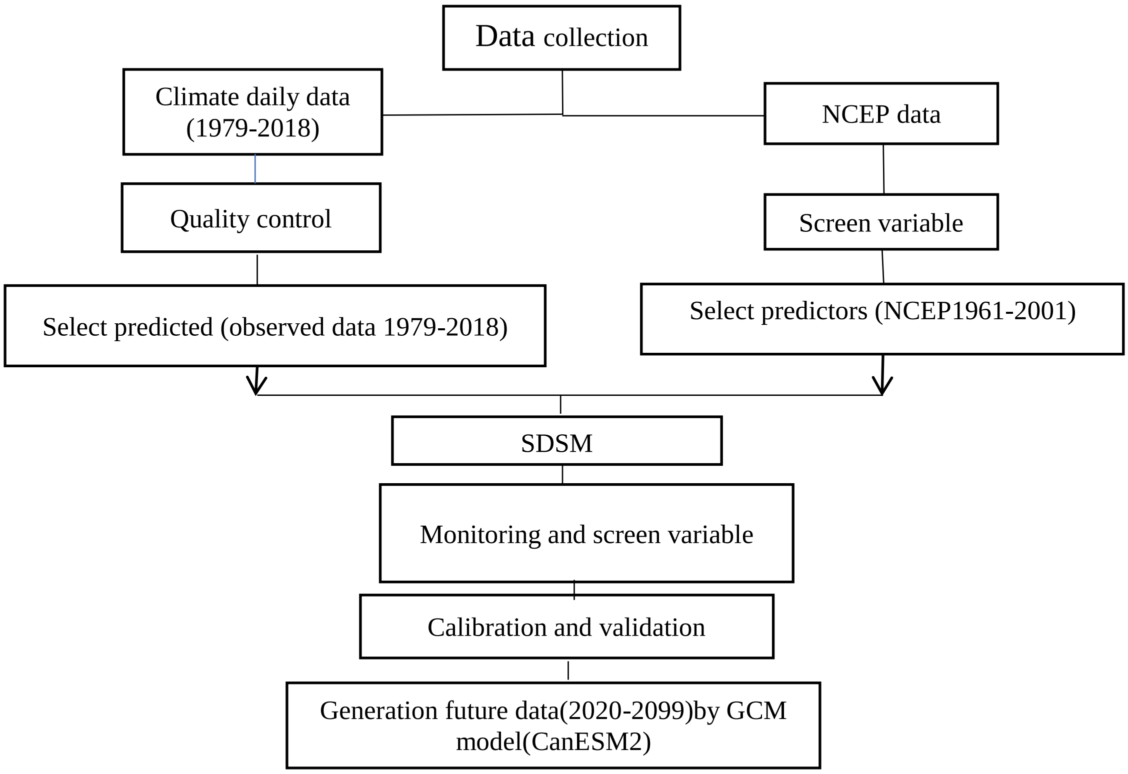

Fig.2. Structure of SDSM Version4.2 for climatic scenarios generation[27][26].

3.2.1 Monitoring and screen variables.

This step's key goal is to make the decision easier Acceptable predictor downscaling criteria. This step is the most difficult mathematical method Simulation downscaling due to predictor collection the form of the climate scenario is largely established. For the current research the most suitable multiple regression model across the entire weather station was evaluated by a correlations analysis of the empirical impact. This was an analyzed correlation between predictors and anticipated, including partial correlation analysis, matrix analyzes and scatter plots.

3.2.2 Calibration and validation

The gathered data of precipitation and air temperature (from1979-2018), which was taken from the (Iraqi Meteorological Organization and Seismology (IMOS), 2018)) were separated into two groups. The first one was from 1979-2000, where utilized in the calibration of the model, while the second group contained the other part of collected data (2001-2018) used to validate the model. The validation stage accuracy was evaluated through using three statistical factors (the root mean square error RMSE, mean bias error MBE, and determination coefficient R^2). Determination coefficient is the highest test of relativity one equivalent meaning (Eq. 1). RMSE is the default variance (prediction errors) of residual and equals zero if the Model forecasts very closely complement findings (Eq. 2). The MBE is the modeling error estimate. The best value is equal to zero but may be negative or positive (Eq. 3).

$$R^2 = \frac{\sum_1^n P_i O_i}{\sqrt{\sum_1^n P_i^2 O_i^2}} \quad (1)$$

$$RMSE = \frac{\sqrt{\sum_1^n (P_i - O_i)^2}}{n} \quad (2)$$

$$MBE = \frac{\sum_1^n (P_i - O_i)}{n} \quad (3)$$

where P_i is the daily value of expected; O_i the daily observation value and n the overall data number.

3.2.3 Generation of climatic scenarios

More than one scenario was considered by the Intergovernmental Panel on Climate Change (IPCC) and in order to compensate for the fluctuations in human activity that could affect climate change, global circulation models (GCMs) were developed using different scenarios for any future emission,[34] . A report examining the amounts of emissions of greenhouse gases, technology growth, land use, land covers, and other human activities is included in the Special Report on Emission Scenarios (SRES). The most pertinent emission scenarios may be A1F1, A1T, A1, A2, A1B, B1 and B2 , [35]. With this in mind, an SDSM model was generated with climate scenarios for the future, these a function of alterations regarding local variables. At this stage of the research, and considering statistical calibration and regression equations between several global scale predictors parameters, e.g., the maximum temperature at study area through baseline interval (1979–2018), a statistical downscaling operation will be carried out on the GCM output CanESM2) under different emissions scenarios (A2, B2, RCP 2.6, RCP 4.5and RCP 8.5). A time series of daily maximum temperatures at local stations will be modeled and generated as applicable to the study time frame.

4 Results and discussion

4.1 Climate change analysis

4.1.1 Precipitation

The downscaling scenarios of precipitation are inherently more complicated than other climate factors scenarios, such as wind, temperature,.. etc. The reason behind that difficulty being in that the daily registered quantities at the various places had relatively poorly with these resolved by predictors of the regional scale. Both precipitation and quantities should be specified as it is conditional to the precipitation method. Unconditional models assume that global ties are directly established. Local wind speeds for example would work with grids and local airflow indices like zonal and southern velocity aspects.

Figure 3 shows a comparison of the average annual precipitation recorded for the verification period (2001 to 2018) with precipitation produced by the final downscale using the CanESM2 model at all local stations in the trial area.

Downscale proceedings rely on two climatic scenarios: A2 and B2 of the CanESM2 model, which are based on annual precipitations for the base years 1979–2018 as well as predicting precipitation for future decades (2020-2099).

Through a process, a strong link has been demonstrated between the data documented for the field of study and the data produced by the SDSM program for the period 1979-2018, as illustrated in figure 3. The RCP2.6, RCP4.5 and RCP8.5 scenarios were compared to determine which one gives the highest rainfall value over the coming years, as we got the highest value, which is 72.66 mm for the month of December(figure 4).

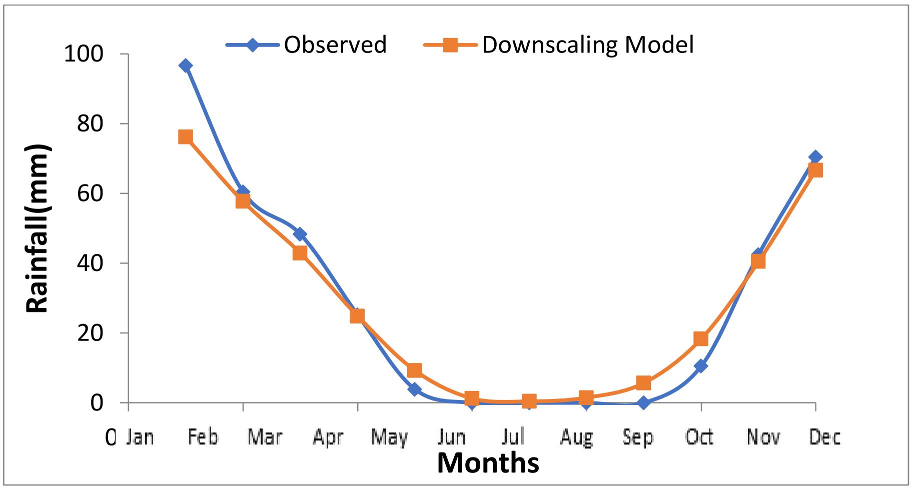

Fig.3. Appears the correspondence between the observed data and the generated data (1979-2018).

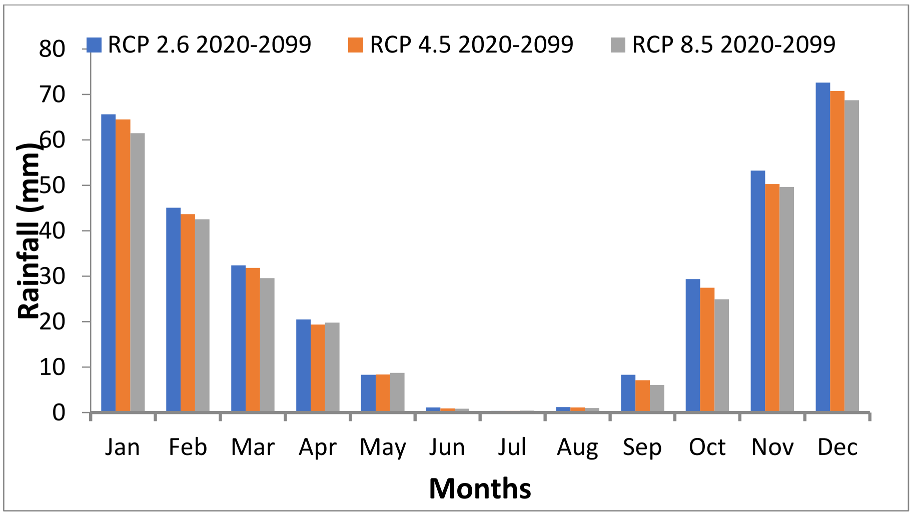

Fig.4. Comparison between RCP2.6,RCP4.5,and RCP8.5 (2020-2099).

4.1.2 Temperature

In order to ascertain the potential of SDSM to simulate the regular minimum, maximum temperatures for future decades, Figure 5, dividing observation information between 1979 and 2018 into two classes was needed to calibrate and validate the models. First data was used between 1979 and 2000. In the period 2001 to 2018, the model was tested for validation and creation of downscale model data. Table 2 presents the average results for temperature variables using the predictive index determination coefficient (R^2) and MBE for the calibration models. R^2 for the maximum temperature is 0.926, the MBE is -0.07812,the RMSE is 3.044495 and the validation model R^2 is 0.9182 while MBE is -0.2417 ,and RMSE is 3.163117. For the calibration model R^2 for the minimum temperature R^2 is 0.8924, the MBE is 0.093689 and the validation model R^2 is 0.8847 while MBE is -0.08285 ,and RMSE is 2.69098. The cross-validation results show that the recently developed regression models are accurate and can be used in the future as distinguishing criteria for controlling daily (minimum and maximum) temperatures. In the context of global climate parameters, the cross-validation results demonstrate that the finally developed models have reasonable accuracy and will in the future predict the expected maximum temperatures. Cross-validation results show that the finally developed regression models are accurate and can be used in the future as distinct criteria to predominate daily (minimum and maximum) temperatures. Within the context of global climate parameters, the cross validation findings demonstrate that the finally developed models have reasonable precision and will in future predict expected maximum temperatures.

Table 3. The calibration results of the downscaled models with basic observation period(1979–2000)and validation results of the downscaled models with basic for observation period(2001–2018) .

Station	Climate variable	R^2	RMSE	MBE
Basra	Maximum temp. calib.	0.926	3.044495	-0.07812
	Maximum temp. valid.	0.918	3.163117	-0.2417
	Minimum temp. calib.	0.892	2.874	0.093689
	Minimum temp. valid.	0.884	2.690981	-0.08285

As for the figure5, it shows the relationship between the recorded data(1979-2018)and the predicted data up to the year(2099)which shows that there is a clear increase in extreme temperatures in the long term, and therefore there will be a clear impact on the amounts of rain.

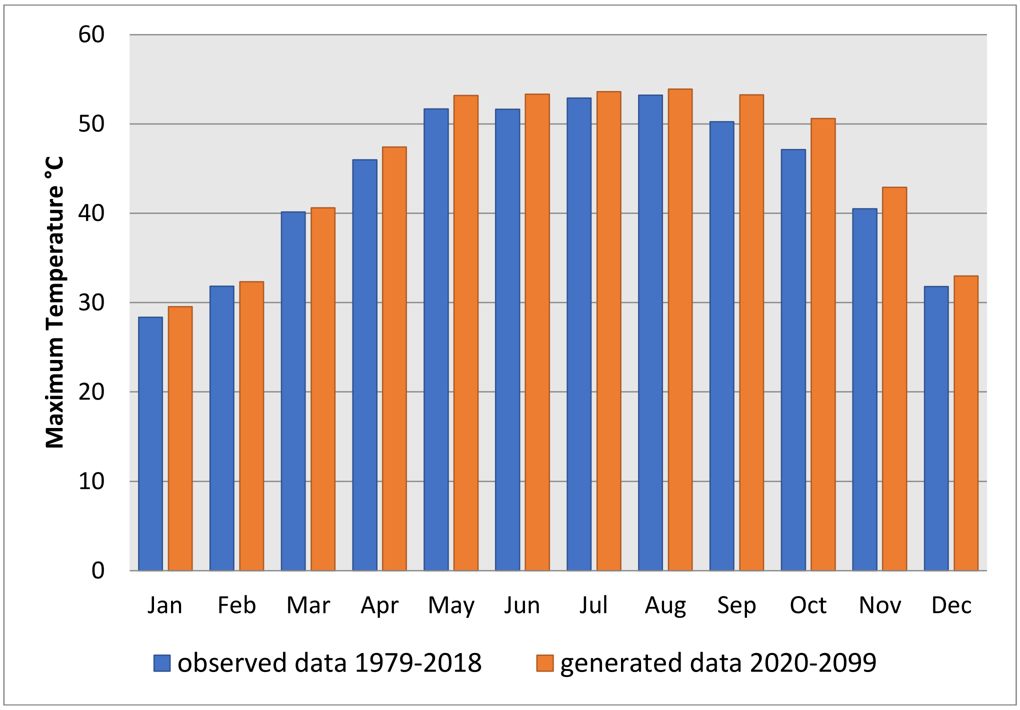

Fig.6 Comparison between observed (1979–2018) and predicted values by CanESM2 model for maximum temperature.

4.1.3The Effect of Climate Change

For the rainy events from 1979-2018 in the study area, the climate change was simulated and based on the flood size, the study analyzed the highest rain intensity using SWMM ,and compared it with the design intensity.

The amount of flooding in the manholes was divided into five stages as follows: -

Stage 1 range from(0 to 0.001)m^3/sec , no flooding.

Stage 2 range from (greater than 0.001 to 0.01)m^3/sec, very light flooding.

Stage 3 range from (greater than 0.01 to 0.02) m^3/sec,medium flooding .

Stage 4 range from (greater than 0.02 to 0.06) m^3/sec,hight flooding .

Stage 5 for greater than 0.06 m^3/sec ,very hight flooding .

By using the program Storm and Sanitary Analysis 2018(SSA) the amounts of rain obtained through the program SDSM were converted into rain intensities in order to study the effect of changing the intensity of rain in the study area and for the near and long years after predicting the expected rain pressures through the SDSM program, the results were 14.5 mm / h, 17.8 mm/hr, 19.5 mm/hr and, 21.5 mm/hr for 2030, 2056, 2075 and 2099 respectively. For a more careful examination of the rainwater drainage network, two rain intensities have been added, namely 35 mm/hr and 49 mm/hr. One of them will be analyzed in addition to two predicted intensities in the SDSM program.

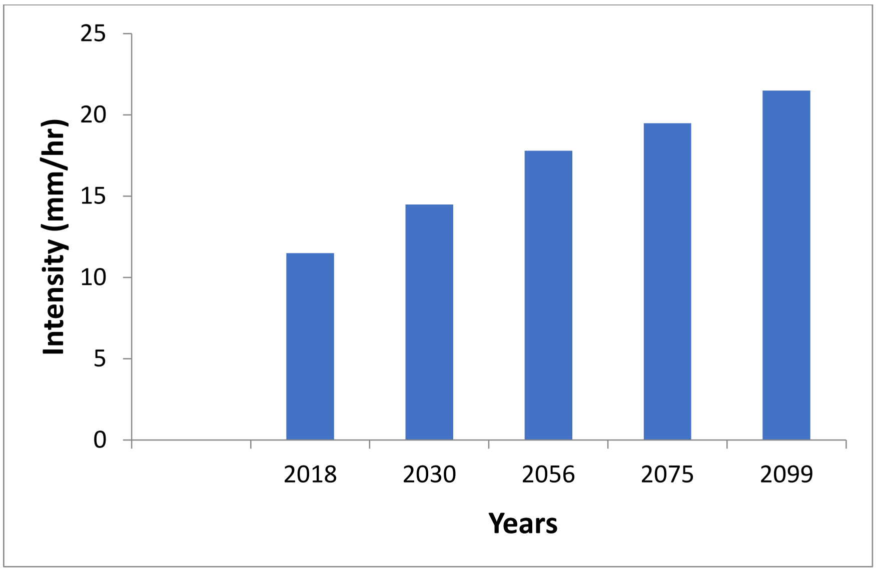

Fig.7 shows the variance between recorded data(2018) and predicted rainfall intensity(2030,2056,2075,and2099).

4.3.1 The Analyzed of The Designed Intensity.

When analyzing the rainwater drainage network for the specified rain intensity when designed which is 11.5 mm / hr for two hours, the behavior of the stormwater drainage network when exposed to an intensity of 11.5 mm / hr, 2.5% of the drainage openings were exposed to floods (first stage), 9.92% were exposed to floods in the second phase, while 2.48% were exposed to floods during the third phase, 2.48% were exposed to floods during the fourth phase, and finally, 0.82% were exposed to floods during the fifth stage.

So, the whole flooding manholes were 22 from 121 with a percent of 18.2, the flood time ranged from 40 to 100 minutes and the maximum total flood was 0.45 m3/s. Figures 7a Illustrate the flooding in the sub-catchment and according to the previously mentioned phases, and Figure 4b also shows the percentages of the flood that occurs in manholes in the study area. From the above results, it is evident that the network was working fine.

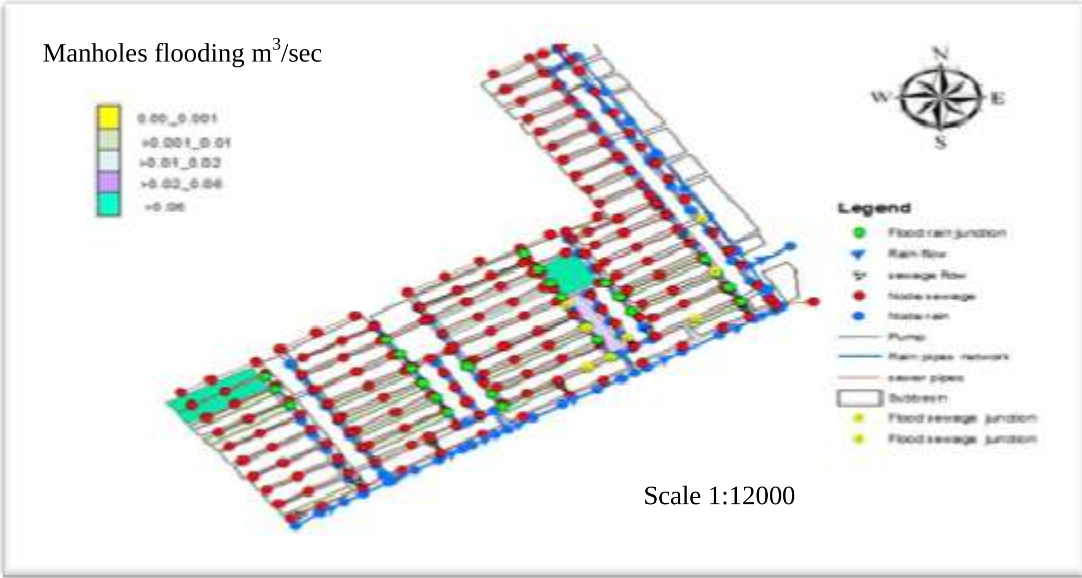

Fig.8 a. The flooding manhole with desgin intensity 11.5 mm/hr.

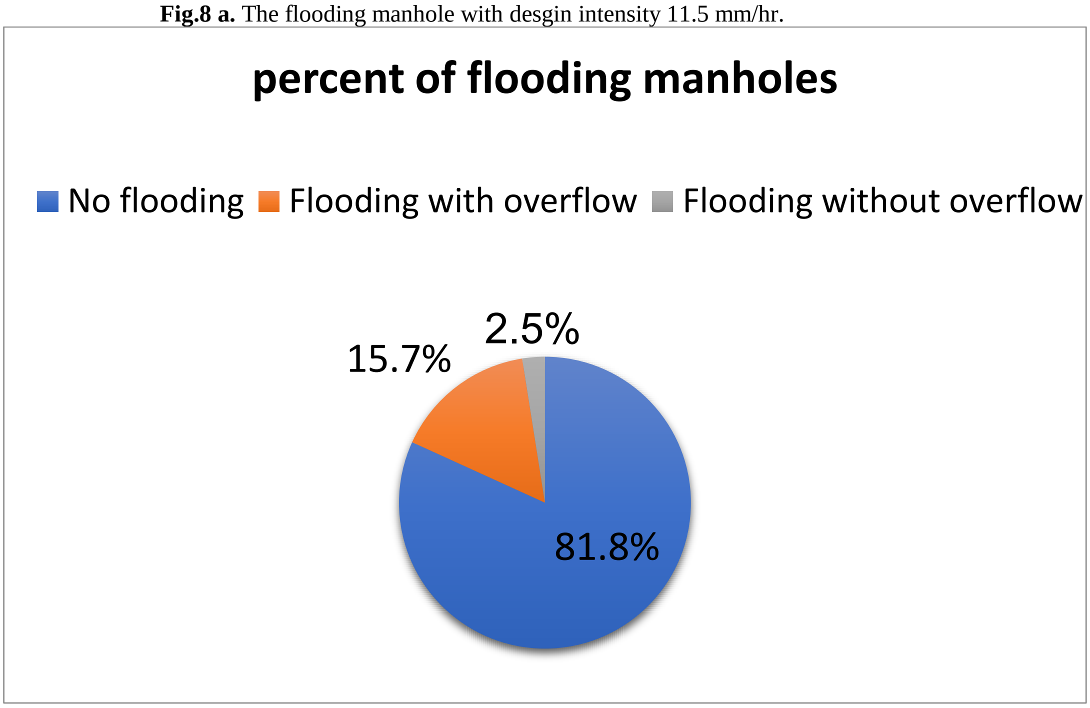

Fig.8 b. The percentage of flooding manholes under desgin intensity 11.5mm/hr.

4.3.5 Rainfall intensity of 21.5 mm/hr

Now we are testing the rainwater drainage network when it is exposed to a intensity of 21.5 mm / hour, which is the expected intensity in 2099. The result was flooding of 9% of the manholes exposed to floods within the first phase, and the percentage of manholes that were exposed to floods in the second phase was 5%, while the percentage of manholes was 5%. During the third stage, 14% were exposed to flooding, while in the fourth stage we see that the percentage of manholes that were exposed to flood is 5.8%, and we also see that 1.7% of the manholes were exposed to floods during the fifth stage. So, the whole flooding manholes were 43 from 121 with a percent of 35.5. The time of the flood ranged between 55 to 120 accurate and maximum overflowing it is 0.87 m3/s.Figure 8a shows the flooding in the sub-catchments and according to the previously mentioned stages, as well as Figure 8b shows the percentages of the flood that occurs to the inspection rooms in the study area. From the above results, it is clear that the network was working well.

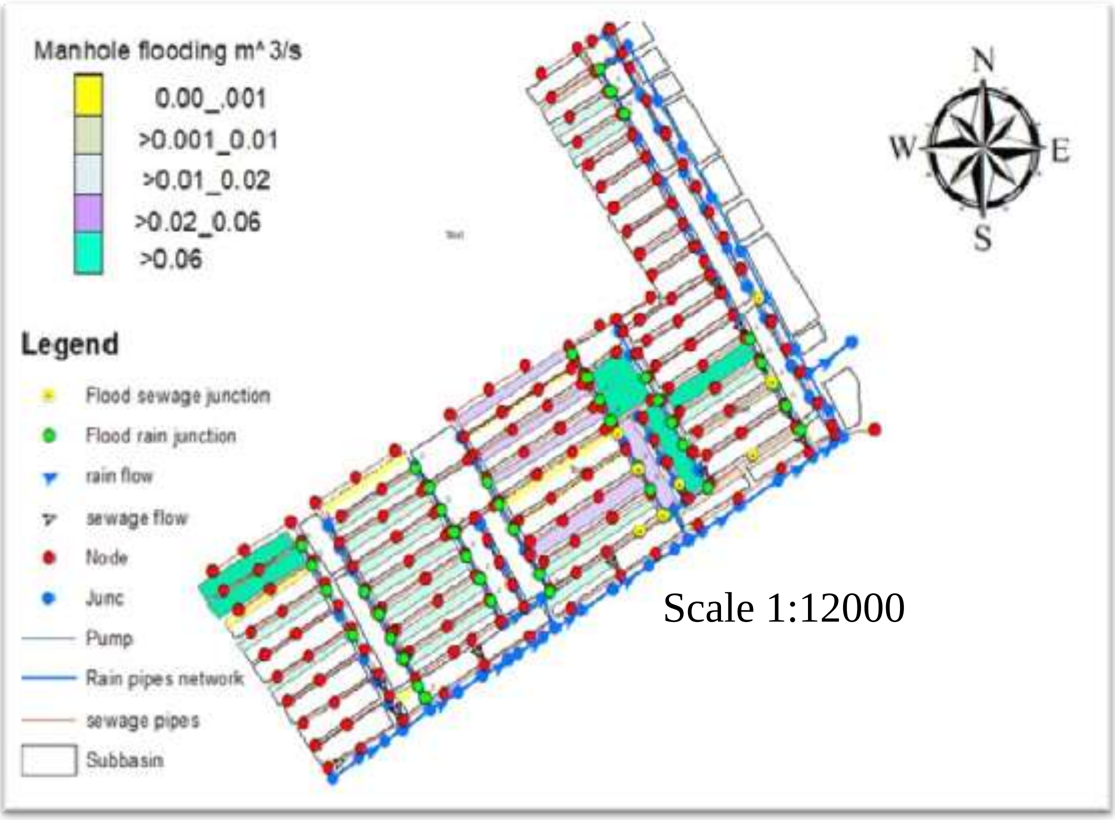

Fig.9 a. The flooding manhole with intensity 21.5 mm/hr

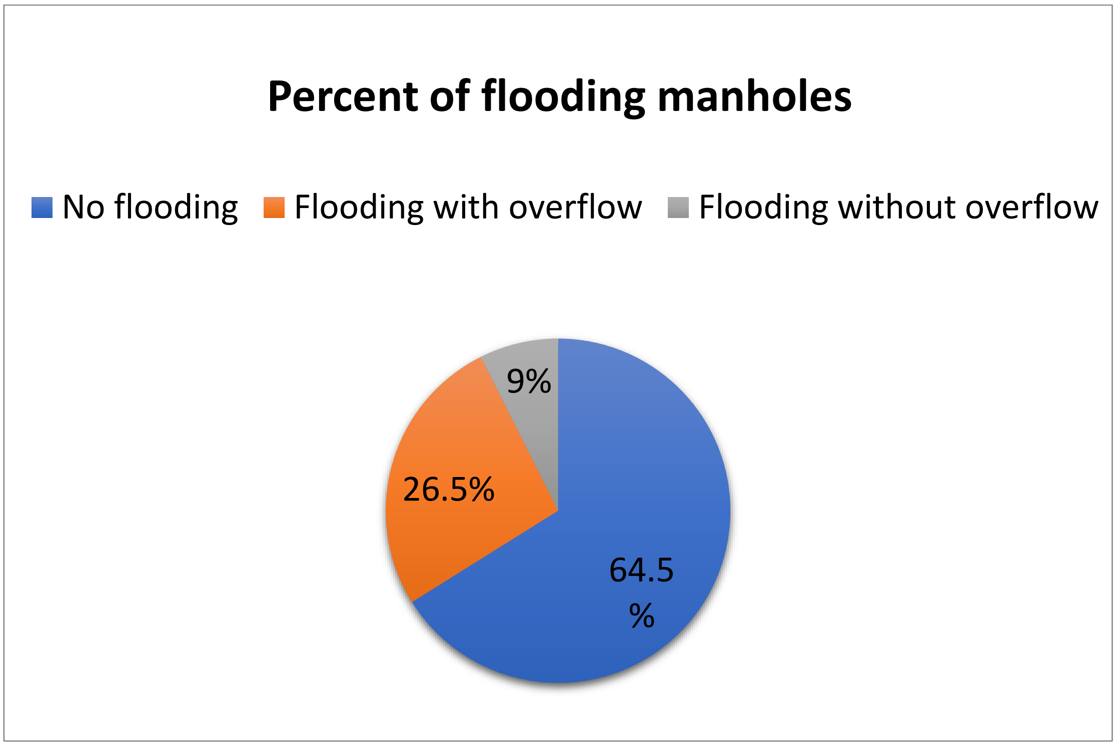

Fig.9 b. The percentage of flooding manholes under intensity 21.5mm/hr

4.4.2 Rainfall intensity of 49 mm/hr.

Through the analysis of the rainwater drainage network when it was exposed to an intensity of 49 mm/hr, which was the un predicted intensity. We noticed that at the first stage near 5% of overall manholes suffered from flooding, but without overground flow. Also, in the next stage (which is the second stage), about 6.61 percent was in flooding case, the third stage flooding manholes percent raised to 3.3.

Finally, the fourth and fifth stage has the most important influence on the network with increasing of the flooding percent of 27.27,4.13 respectively .Furthermore, the whole flooding manholes were 56 from 121 with a percent of 46.3. The flooding time ranged between 55 to 120 minutes, and the total maximum overflow is 2.18 m3/s.

Figure 10a shows that flooding in the sub-catchments and according to the previously mentioned stages, as well as figure10b shows that the percentages of the flood that occurs to the inspection rooms in the study area. From the above results, it is clear that the network was working well under this intensity.

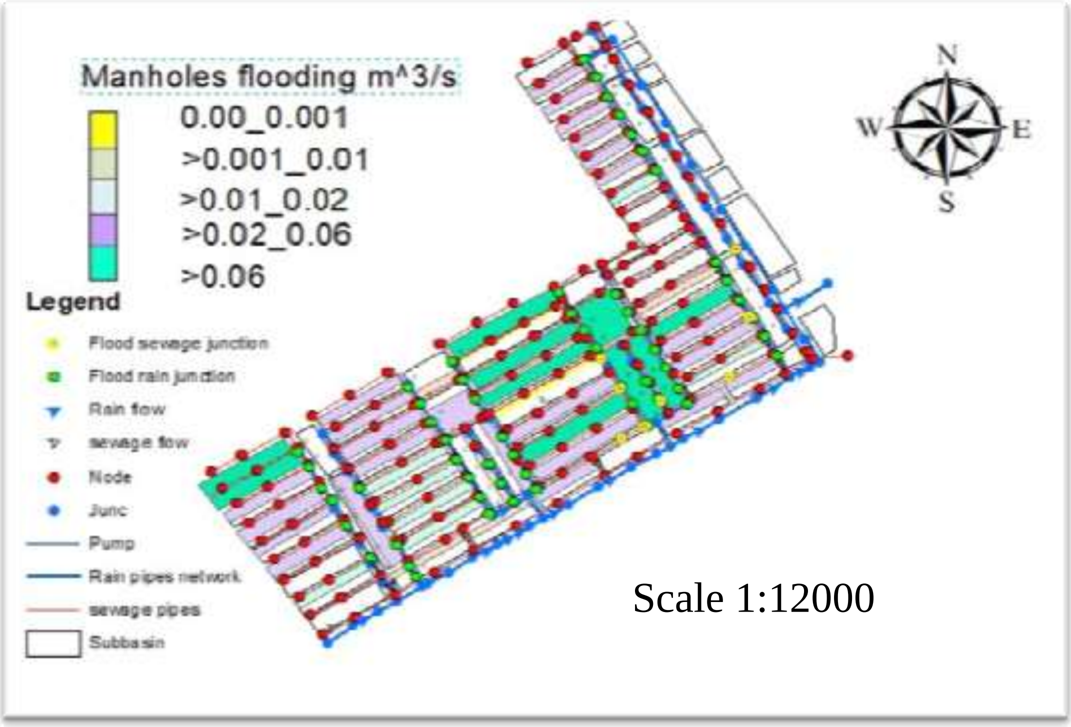

Fig.10 a. The flooding manhole with intensity 49 mm/hr.

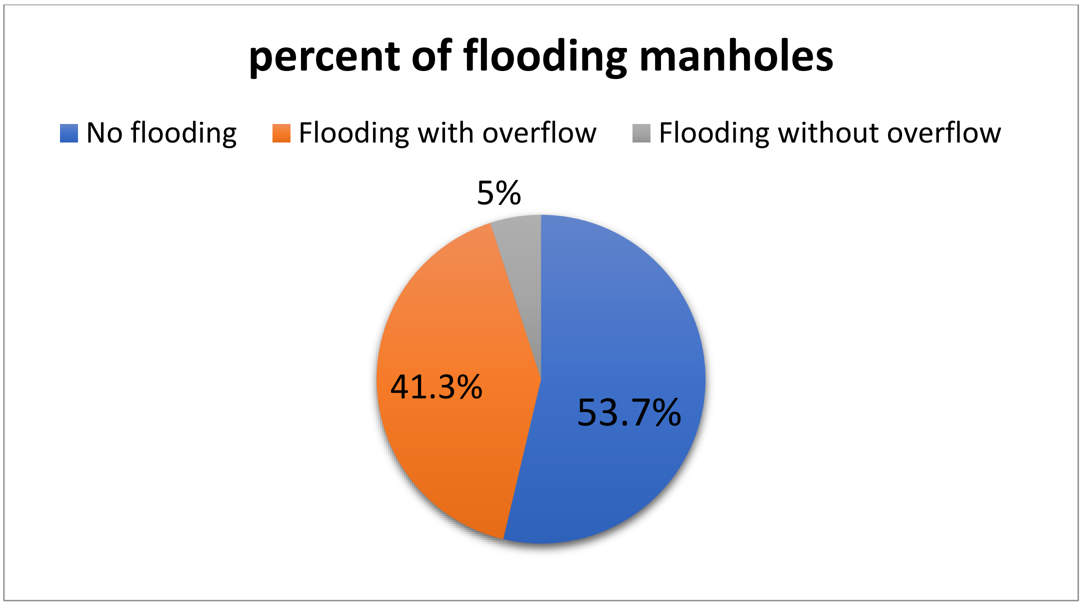

Fig.10 b. The percentage of flooding manholes under intensity 49mm/hr.

5. Conclusions

Climate change is a growing global problem, particularly the lack of rain and the rise in temperature. This study tested the impact of climate change on rainfall from 2020 to 2099 using CanESM2 output models, using the RCP 2.6, RCP 4.5 and RC8.5 scenarios. The results of the analysis showed that four rain intensities were obtained for the near and far future, as follows: 14.5 mm/hr, 17.8 mm/hr, 9.5 mm/hr and 21.5 mm/hr. The aim of this study was to determine the performance of the rainwater drainage network when exposed to expected or unexpected extreme events of climate change.

The conclusions that are based on the results can be summarized as follows:

1-The SDSM model was calibrated and excellent, and the verification results showed that the mean error (me) is very close to zero(-0.00818 to -0.2342) for the canESM2 model, and at the same time the value of the coefficient of determination R2 was(0.844 to 0.8954).

2- The maximum temperature increased in the long term in the year 2099 and ranged between (0.14 to 1.07) degrees Celsius, and the minimum temperatures increased between (0.19 to 0.45) degrees Celsius and in the long term, specifically in the year. 2099.

3-Rainfall,the model CanESM2 in 2030 was predicted by scenarios RCP2.6,RCP4.5,RCP8.5 the annual rainfall 109.97mm,113.2mm,111.45mm respectively, and an increase of 3.5%, 2.9, 1.3% respectively more than the recorded data.

4-The model CanESM2 in 2056 was predicted by scenarios RCP2.6,RCP4.5,RCP8.5 the annual rainfall114.76mm,119mm,117.93mm respectively, and an increase of 4.4%, 8.2%, 7.2% respectively more than the recorded data.

5- The model CanESM2 in 2075 was predicted by scenarios RCP2.6,RCP4.5,RCP8.5 the annual rainfall117.6mm,119.8mm,118.12mm respectively, and an increase of 6.9%, 8.9%, 7.41% respectively more than the recorded data.

6- The model CanESM2 in 2099 was predicted by scenarios RCP2.6,RCP4.5,RCP8.5 the annual rainfall100.8mm,98.6 mm,96.5mm respectively, and decrease of 8.3%, 10.4%, 12.2% respectively more than the recorded data.

7-The storm drainage system, when analyzed in the SWMM program, provides the rainfall intensity 14.5 mm/hr in the year 2030 in winter, and reaching the fourth stage (0.02-0.06) m3 /s by the proportion of 2.48% and the fifth stage(more than 0.06) by the proportion of 0.82% and the duration of the flood from 50 to 120 minutes.

8- The storm drainage system, when analyzed in the SWMM program, provides the rainfall intensity 17.8 mm/hr in the year 2056 in winter, and reaching the fourth stage (0.02-0.06) m3 /s by the proportion of 1.65% and the fifth stage(more than 0.06)m3 /s by the proportion of 1.65% and the duration of the flood from 55 to 120 minutes.

9- The storm drainage system, when analyzed in the SWMM program, provides the rainfall intensity 19.5 mm/hr in the year 2077 in winter, and reaching the fourth stage (0.02-0.06) m3 /s by the proportion of 3.3 % and the fifth stage(more than 0.06)m3 /s by the proportion of 1.7% and the duration of the flood from 50 to 110 minutes.

10- The storm drainage system, when analyzed in the SWMM program, provides the rainfall intensity 21.5 mm/hr in the year 2099 in winter, and reaching the fourth stage (0.02-0.06) m3 /s by the proportion of 5.8% and the fifth stage(more than 0.06)m3 /s by the proportion of 1.7 % and the duration of the flood from 55 to 120 minutes.

References

[1] E. Houghton, Climate change 1995: The science of climate change: contribution of working group I to the second assessment report of the Intergovernmental Panel on

Climate Change, vol. 2. Cambridge University Press, 1996.
[2] Hassan, W.H., 2020. Climate change impact on groundwater recharge of Umm er Radhuma unconfined aquifer Western Desert, Iraq. International Journal of Hydrology Science and Technology, 10(4), pp.392-412.
[3] Hassan, W.H. and Nile, B.K., 2021. Climate change and predicting future temperature in Iraq using CanESM2 and HadCM3 modeling. Modeling Earth Systems and Environment, 7(2), pp.737-748.
[4] Hassan, W.H., 2021. Climate change projections of maximum temperatures for southwest Iraq using statistical downscaling. Climate Research, 83, pp.187-200.
[5] L. Bijlsma et al., “Coastal zones and small islands,” Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 289–324, 1996.
[6] C. Denault, R. G. Millar, and B. J. Lence, “Assessment of possible impacts of climate change in an urban catchment 1,” *JAWRA J. Am. Water Resour. Assoc.*, vol. 42, no. 3, pp. 685–697, 2006.
[7] M. J. Cambez, J. Pinho, and L. M. David, “Using SWMM 5 in the continuous modelling of stormwater hydraulics and quality,” in *11th International Conference on Urban Drainage, Edinburgh, Scotland, UK*, 2008, vol. 18.
[8] S. Y. Park, K. W. Lee, I. H. Park, and S. R. Ha, “Effect of the aggregation level of surface runoff fields and sewer network for a SWMM simulation,” *Desalination*, vol. 226, no. 1–3, pp. 328–337, 2008.
[9] M. O. Nayel, B. K. Nile, and H. A. M. Al-Hamami, “Estimation of the floods that occur in the drainage network during the rainy season,” *J. Eng. Appl. Sci.*, vol. 13, no. Specialissue10, pp. 8178–8187, 2018, doi: 10.3923/jeasci.2018.8178.8187.
[10] K. A. Mohsen, B. K. Nile, and W. H. Hassan, “Experimental work on improving the efficiency of storm networks using a new galley design filter bucket.,” in *IOP Conference Series: Materials Science and Engineering*, 2020, vol. 671, no. 1, p. 12094.
[11] B. K. Nile, W. H. Hassan, and B. A. Esmaeel, “An evaluation of flood mitigation using a storm water management model [SWMM] in a residential area in Kerbala, Iraq,” in *IOP Conference Series: Materials Science and Engineering*, 2018, vol. 433, no. 1, p. 12001.
[12] Nile, B.K., Hassan, W.H. and Alshama, G.A., 2019. Analysis of the effect of climate change on rainfall intensity and expected flooding by using ANN and SWMM programs. ARPN Journal of Engineering and Applied Sciences, 14(5), pp.974-984.
[13] Y. W. Li, X. Y. You, M. Ji, X. D. Wang, L. J. Zhao, and L. M. Pan, “Optimization of rainwater drainage system based on SWMM model,” *China Water & Wastewater*, vol. 26, no. 23, pp. 40–43, 2010.
[14] S. R. Mohammed, B. K. Nile, and W. H. Hassan, “Modelling Stilling Basins for Sewage Networks,” in *IOP Conference Series: Materials Science and Engineering*, 2020, vol. 671, no. 1, p. 12111.
[15] K. L. Meierdiercks, J. A. Smith, M. L. Baeck, and A. J. Miller, “Analyses of Urban Drainage Network Structure and its Impact on Hydrologic Response 1,” *JAWRA J. Am. Water Resour. Assoc.*, vol. 46, no. 5, pp. 932–943, 2010.
[16] F. A. Beling, J. I. B. Garcia, E. Paiva, G. A. P. Bastos, and J. B. D. Paiva, “Analysis of

the SWMM model parameters for runoff evaluation in periurban basins from southern Brazil," in *12nd international conference on urban drainage*, 2011, pp. 11–16.
[17] M. Jung, H. Kim, K. J. B. Mallari, G. Pak, and J. Yoon, "Analysis of effects of climate change on runoff in an urban drainage system: a case study from Seoul, Korea," *Water Sci. Technol.*, vol. 71, no. 5, pp. 653–660, 2015.
[18] H. A. Obaid, S. Shahid, K. N. B. K. N. Basim, and C. Shreeshivadasan, "Modeling sewerage overflow in an urban residential area using storm water management model," *Malaysian J. Civ. Eng.*, vol. 26, no. 2, 2014.
[19] W. H. Hassan, B. K. Nile, and B. A. Al-Masody, "Climate change effect on storm drainage networks by storm water management model," *Environ. Eng. Res.*, vol. 22, no. 4, pp. 393–400, 2017.
[20] Hassan, W.H. and Hashim, F.S., 2021. Studying the impact of climate change on the average temperature using CanESM2 and HadCM3 modelling in Iraq. International Journal of Global Warming, 24(2), pp.131-148.
[21] Y. B and P. Coulibaly, "Hydrologic impact of climate change in the Saguenay watershed: comparison of downscaling methods and hydrologic models," *J. Hydrol.*, vol. 307, no. 1–4, pp. 145–163, 2005.
[22] Hassan, W.H., 2019. Application of a genetic algorithm for the optimization of a location and inclination angle of a cut-off wall for anisotropic foundations under hydraulic structures. Geotechnical and Geological Engineering, 37(2), pp.883-895.

[23] H. J. Fowler, S. Blenkinsop, and C. Tebaldi, "Linking climate change modelling to impacts studies: recent advances in downscaling techniques for hydrological modelling," *Int. J. Climatol. A J. R. Meteorol. Soc.*, vol. 27, no. 12, pp. 1547–1578, 2007.
[24] Hassan, W.H., Attea, Z.H. and Mohammed, S.S., 2020. Optimum layout design of sewer networks by hybrid genetic algorithm. Journal of Applied Water Engineering and Research, 8(2), pp.108-124.

[25] R. L. Wilby, C. W. Dawson, and E. M. Barrow, "SDSM—a decision support tool for the assessment of regional climate change impacts," *Environ. Model. Softw.*, vol. 17, no. 2, pp. 145–157, 2002.
[26] W. H. Hassan and F. S. Hashim, "The effect of climate change on the maximum temperature in Southwest Iraq using HadCM3 and CanESM2 modelling," *SN Appl. Sci.*, vol. 2, no. 9, pp. 1–11, 2020.
[27] J. P. Evans, "21st century climate change in the Middle East," *Clim. Change*, vol. 92, no. 3, pp. 417–432, 2009.
[28] L. Nie, O. Lindholm, G. Lindholm, and E. Syversen, "Impacts of climate change on urban drainage systems–a case study in Fredrikstad, Norway," *Urban Water J.*, vol. 6, no. 4, pp. 323–332, 2009.
[29] S. Shahid, M. Alamgir, X. J. Wang, and S. Eslamian, "Climate change impacts on and adaptation to groundwater," *Handb. Drought Water Scarcity Environ. Impacts Anal. Drought Water Scarcity*, vol. 2, pp. 107–124, 2017.
[30] P. Ranjan, S. Kazama, and M. Sawamoto, "Effects of climate change on coastal fresh groundwater resources," *Glob. Environ. Chang.*, vol. 16, no. 4, pp. 388–399, 2006.
[31] J. Sansom and J. A. Renwick, "Climate change scenarios for New Zealand rainfall," *J. Appl. Meteorol. Climatol.*, vol. 46, no. 5, pp. 573–590, 2007.
[32] R. L. Wilby, C. W. Dawson, and E. M. Barrow, "SDSM 4.2–A decision support tool

for the assessment of regional climate change impacts (User Manual)," *Clim. Impacts Adapt. Res. Program.*, 2007.

[33] W. H. Al-Mussawi, "Kriging of groundwater level-a case study of Dibdiba Aquifer in area of Karballa-Najaf," *J. kerbala Univ.*, vol. 6, no. 1, pp. 170–182, 2008.

[34] S. Solomon, "The physical science basis: Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change," *Intergov. Panel Clim. Chang. (IPCC), Clim. Chang. 2007*, vol. 996, 2007.

[35] R. L. Wilby and C. W. Dawson, "The statistical downscaling model: insights from one decade of application," *Int. J. Climatol.*, vol. 33, no. 7, pp. 1707–1719, 2013.